

FIELD OF THE INVENTION

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The use of a radar device in the automotive sector is also described in the dissertation "Radar Systems for the Automatic Distance Control in Automobiles" by R. Mende, Technical University Carolo-Wilhelmina, Braunschweig, 1999, as well as
5 German Published Patent Application No. 199 22 411, German Published Patent Application No. 42 44 608 and German Published Patent Application No. 100 25 844.

German Published Patent Application No. 199 22 411 describes a
10 CW radar method (continues wave radar method) for measuring distances and relative speeds between a vehicle and one or several obstacles, in which a transmission signal is made up of at least four consecutive blocks having in each case different gradients. In a distance-relative speed diagram,
15 first the intersections of all straight lines from two blocks of all discovered frequency positions are calculated. For validating these intersections, they are checked as to whether in the Fourier spectrum of a third block there exists a peak at a frequency position, whose associated straight line in the
20 distance-relative speed diagram intersects a surrounding region of the intersection. The intersections validated in this manner are subjected to a second condition, whether in the Fourier spectrum of a fourth block there exists a peak at a frequency position, whose associated straight line in the
25 distance-relative speed diagram intersects a surrounding region of the intersection. The intersections are regarded as valid if they satisfy both conditions.

German Published Patent Application No. 42 44 608 describes a
30 radar method for measuring distances and relative speeds between a vehicle and obstacles in front of it, comprising an emission of continuous transmission signals, simultaneous reception of signals reflected by the obstacles during the emission of the continuous transmission signals, mixing of the
35 reflected signals with the continuous transmission signals for

obtaining inphase and quadrature signals and processing of these signals into output signals for the distances and relative speeds of the obstacles, the continuous transmission signals being broken down into constant frequency increments of constant time duration without time interval with respect to each other and at each constant frequency increment of the reflected received signal a complex sampling value being recorded and mixed with the transmission signal of the same constant frequency increment.

German Published Patent Application No. 100 25 844 describes an incrementally linear frequency-modulated transmission signal, at least two incrementally linear frequency-modulated ramps being mutually interwoven. Characteristic in this regard is the fact that these two or more ramps have a constant frequency shift with respect to one another. By frequency measurement and phase difference measurement it is possible to calculate unambiguously the distance of the object and the speed of the object from the received signals.

In addition it is describe in German Published Patent Application No. 43 31 440 to form for the radar device I/Q signal pairs for the signal evaluation, a phase shifter being connected between a radar antenna and a radar front end, an evaluation circuit having two signal channels on the input side, the radar front end being connectable via a channel switch to one of the two signal channels, the phase shifter and the channel switch being clocked synchronously and the phase shifter switching the phase between 0° and 45° with each clock cycle.

A Doppler radar device for a vehicle for indicating a distance between the vehicle and an obstacle is described in German Published Patent Application No. 689 13 423.

SUMMARY

Example embodiments of the present invention may provide a measuring device having an improved measuring accuracy, e.g., as compared to that described in German Published Patent Application No. 100 50 278. For this purpose it may be possible, with the aid of the measuring device, to keep the occurrence of so-called ghost targets low or to eliminate it entirely, to allow for a measuring time of less than 10ms and to allow for the detection of objects at a very close range (0m ... 1m) as well as at a medium and remote range.

According to example embodiments of the present invention a measuring device, e.g., a measuring device for a motor vehicle, is for measuring a distance between the measuring device and at least one object and/or for measuring a speed difference between the measuring device and the at least one object, the measuring device including an emitting device for sending a transmission signal, which includes at least two signal portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions, at least two signal portions of a signal portion sequence differing in their frequency in each case by one differential frequency, the differential frequency of the first signal portion sequence differing from the differential frequency of the second signal portion sequence, e.g., by at least 5%, e.g., by at least 10%.

The measuring device may include a receiving device for receiving a reflection signal of the transmission signal reflected by the at least one object and , e.g., a mixer for mixing the first signal portion sequence with a portion of the first signal portion sequence reflected by the at least one object to form a first mixed signal. The measuring device may additionally include an evaluation device for ascertaining the frequency or frequencies of the first mixed signal. The

evaluation may occur with the aid of an FFT (fast Fourier transform), for example.

The evaluation device may allow for the distance between the measuring device and the at least one object and/or the speed difference between the measuring device and the at least one object to be determined as a function of the measured frequencies of the first mixed signal.

10 The mixer may allow for the second signal portion sequence to be mixed with a portion of the second signal portion sequence reflected by the at least one object to form a second mixed signal, and the evaluation device may allow for the measured frequencies of the second mixed signal to be ascertained.

15 The evaluation device may allow for the distance between the measuring device and the at least one object and/or the speed difference between the measuring device and the at least one object to be determined as a function of the measured frequencies of the first mixed signal and of the measured frequencies of the second mixed signal.

20 The evaluation device may allow for the difference between the absolute phase of the first mixed signal and the absolute phase of the second mixed signal to be determined.

25 The evaluation device may allow for the distance between the measuring device and the at least one object and/or the speed difference between the measuring device and the at least one object to be determined as a function of the difference between the phase of the first mixed signal and the phase of the second mixed signal.

The emitting device and the receiving device may each include an antenna. The emitting device and the receiving device, however, may also be implemented by a common antenna.

- 5 The emitting device may include an optical element, e.g., a laser. The receiving device may include a light-sensitive element, e.g., a photoelement or a photodiode, which may be suited for measuring the phase of the reflected laser light.
- 10 According to example embodiments of the present invention, a method is for measuring a distance between an emitting device and at least one object and/or for measuring a speed difference between the emitting device and the at least one object, a transmission signal having at least two signal
- 15 portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions being sent by the emitting device, at least two signal portions of a signal portion sequence differing in their frequency in each case by
- 20 a non-constant differential frequency. The differential frequency of the first signal portion sequence may differ from the differential frequency of the second signal portion sequence, e.g., by at least 5%, e.g., by at least 10%.
- 25 A reflection signal of the transmission signal reflected by the at least one object may be received, e.g., the first signal portion sequence may be mixed with a portion of the first signal portion sequence reflected by the at least one object to form a first mixed signal, and e.g., the dominating
- 30 (measured) frequencies of the first mixed signal may be ascertained.

The distance between the emitting device and the at least one object and/or the speed difference between the emitting device

and the at least one object may be determined as a function of the dominating frequencies of the first mixed signal.

The second signal portion sequence may be mixed with a portion
5 of the second signal portion sequence reflected by the at least one object to form a second mixed signal, and the dominating frequencies of the second mixed signal may be ascertained.

10 The distance between the emitting device and the at least one object and/or the speed difference between the emitting device and the at least one object may be determined as a function of the dominating frequencies of the first mixed signal and of the dominating frequencies of the second mixed signal.

15 The difference between the phase of the first mixed signal and the phase of the second mixed signal may be determined, and the distance between the emitting device and the at least one object and/or the speed difference between the emitting device
20 and the at least one object may be determined as a function of the differences between the phases of the first mixed signal and the phases of the second mixed signal.

A motor vehicle in present context may include a land vehicle
25 that may be used individually in road traffic. However, motor vehicles in the present context should not be considered to be restricted to land vehicles having an internal combustion engine.

30 Further aspects and details are of example embodiments of the present invention are described in more detail below with reference to the appended Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

35 Fig. 1 is a front view of a motor vehicle.

Fig. 2 is a side view of a motor vehicle.

Fig. 3 illustrates an exemplary embodiment of a radar device.

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Fig. 4 illustrates an exemplary embodiment of a frequency-time diagram.

10 Fig. 5 illustrates an exemplary embodiment of an optical measuring device.

DETAILED DESCRIPTION

Fig. 1 and Fig. 2 illustrate a motor vehicle 1 in an exemplary embodiment. Fig. 1 is a front view of motor vehicle 1, and
15 Fig. 2 is a side view of motor vehicle 1. Motor vehicle 1 has a front bumper 2 and a rear bumper 3. In the exemplary embodiment illustrated, front bumper 2 has distance and/or speed sensors 10, 11, 12, 13, 14, 15, 16 for measuring a distance R between motor vehicle 1 and at least one object or
20 obstacle 20 such as another motor vehicle, for example, and/or for measuring a speed difference v between motor vehicle 1 and the at least one object or obstacle 20, speed difference v being the difference between the speed v_H of obstacle 20 and the speed v_F of motor vehicle 1.

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Depending on the application of distance and/or speed sensors 10, 11, 12, 13, 14, 15, 16, more or fewer distance and/or speed sensors may be arranged on bumper 2. This means that it is also possible that only one sensor is used. Alternatively
30 or additionally, distance and/or speed sensors may also be arranged on rear bumper 3, on side mirrors 4, 5, on side doors 6, 7, on A, B, C pillars and/or on a hatchback 8, etc. The distance and/or speed sensors may be oriented in different directions and/or at different levels. Examples of the
35 application of such distance and/or speed sensors are

described in "Radar Systems for the Automatic Distance Control in Automobiles" by R. Mende, Technical University Carolo-Wilhelmina, Braunschweig, 1999.

5 Fig. 3 illustrates a radar device 30, which is usable as a distance and/or speed sensor 10, 11, 12, 13, 14, 15, 16, for example. Radar device 30 has a radar sensor 40 and an evaluation device 41. Radar device 30 has an oscillator or a signal generator 31 for producing a transmission signal $s(t)$,
10 a transmitting antenna 35 for emitting the transmission signal $s(t)$ and a receiving antenna 36 for receiving a reflection signal $r(t)$ of the emitted transmission signal $s(t)$ reflected by an object such as obstacle 20. t indicates time in this context.

15 Transmission signal $s(t)$ produced by signal generator 31 includes at least two signal portion sequences, a first signal portion sequence and a second signal portion sequence, having each at least two temporally alternating signal portions, the
20 at least two signal portions of a signal portion sequence differing in their frequency in each case by one differential frequency, and the differential frequency of the first signal portion sequence differing from the differential frequency of the second signal portion sequence, e.g., by at least 5%,
25 e.g., by at least 10%. An exemplary embodiment of such a transmission signal is illustrated in Fig. 4 in a frequency-time diagram.

In this context, A_1, A_2, A_3, \dots indicate the signal portions
30 of a first signal portion sequence $A(t)$ and B_1, B_2, B_3, \dots indicate the signal portions of a second signal portion sequence $B(t)$. Such signal portions are also called chirps. In the present exemplary embodiment, the time durations T_{Burst} for signal portions A_1, A_2, A_3, \dots and B_1, B_2, B_3, \dots are of
35 equal length. Time duration T_{Burst} of signal portions $A_1, A_2,$

A3, ... is illustrated in Fig. 4 by a solid line and time duration T_{Burst} of signal portions B1, B2, B3, ... is illustrated by a dashed line.

- 5 The frequency within a signal portion A1, A2, A3, ... or B1, B2, B3, ... may be a constant carrier frequency $f_T(t)$, but it may also be a constant carrier frequency $f_T(t)$ modulated by a modulation frequency.
- 10 The individual signal portions A1, A2, A3, ... of first signal portion sequence A(t) differ in their frequency or their carrier frequency $f_T(t)$ in each case by a differential frequency $f_{\text{Hub},A}/(N-1)$, $f_{\text{Hub},A}$ being the difference between the carrier frequency of first signal portion A1 of first signal
- 15 portion sequence A(t) and the carrier frequency of the Nth signal portion of the first signal portion sequence A(t), and N being the number of signal portions A1, A2, A3, ... of first signal portion sequence A(t). The individual signal portions B1, B2, B3, ... of first signal portion sequence B(t) differ
- 20 in their frequency or their carrier frequency $f_T(t)$ in each case by a differential frequency $f_{\text{Hub},B}/(N-1)$, $f_{\text{Hub},B}$ being the difference between the carrier frequency of first signal portion B1 of second signal portion sequence B(t) and the carrier frequency of the Nth signal portion of the second
- 25 signal portion sequence B(t), and N being the number of signal portions B1, B2, B3, ... of first signal portion sequence B(t). It may be provided to choose the differential frequency $f_{\text{Hub},A}/(N-1)$ of the first signal portion sequence A(t) to differ from the differential frequency $f_{\text{Hub},B}/(N-1)$ of the second
- 30 signal portion sequence B(t), e.g., by at least 5%, e.g., by at least 10%.

Additionally, a frequency shift f_{Shift} may be provided between signal portion A1 of first signal portion sequence A(t) and

35 signal portion B1 of second signal portion sequence B(t).

Accordingly, first signal portion sequence A(t) results in

$$A(t) = \sum_{n=0}^{N-1} \cos \left(2\pi \cdot \left(f_{TA1} + \frac{n}{N-1} \cdot f_{Hub,A} \right) \cdot t \right) \cdot \text{rect} \left(\frac{t}{T_{Burst}} - \frac{1}{2} - 2n \right)$$

5 and the second signal portion sequence B(t) in

$$B(t) = \sum_{n=0}^{N-1} \cos \left(2\pi \cdot \left(f_{TA1} + f_{Shift} + \frac{n}{N-1} \cdot f_{Hub,B} \right) \cdot t \right) \cdot \text{rect} \left(\frac{t}{T_{Burst}} - \frac{1}{2} - (2n+1) \right)$$

where f_{TA1} refers to the carrier frequency of signal portion A1 and rect refers to the rectangle function.

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The transmission signal s(t) thus results in

$$s(t) = A(t) + B(t)$$

15 Via a coupler 32, transmission signal s(t) is supplied to a mixer 38 for mixing transmission signal s(t) and reflection signal r(t). Mixer 38 outputs an inphase signal I(t).

Via another coupler 33, transmission signal s(t) is
20 additionally supplied to a phase shifter 37, which shifts the phase of transmission signal s(t) with respect to the carrier frequency by 90°, that is, by $\pi/2$. The phase-shifted transmission signal is supplied to a mixer 39 for mixing the phase-shifted transmission signal and the reflection signal
25 r(t), which is supplied to mixer 39 via a coupler 34. Mixer 39 outputs a quadrature signal Q(t).

Inphase signal I(t) and quadrature signal Q(t) are mixed signals in the present context.

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Radar device 30 has a multiplier 42, which is used to multiply quadrature signal Q(t) by the complex number j to

yield $jQ(t)$. $I(t)$ and $jQ(t)$ are added to form a complex mixed signal $m(t)$. Complex mixed signal $m(t)$ is a mixed signal in the present context. Radar device 30 additionally has a frequency analyzer 43, which is used to form a spectrum $M(k)$ of complex mixed signal $m(t)$ over frequency k . Using a detector 44, the dominating frequency k_A of mixed signal $m(t)$ is ascertained with respect to first signal sequence $A(t)$, and the dominating frequency k_B of mixed signal $m(t)$ is ascertained with respect to second signal sequence $B(t)$.

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The processing of the individual signal sequences $A(t)$ and $B(t)$ may occur separately by temporal separation such that with the aid of mixers 38 and 39 first signal portion sequence $A(t)$ is mixed with a portion of first signal portion sequence $A(t)$ (of reflection signal $r(t)$) reflected by the at least one object 20 to form a first mixed signal $I_A(t)$, $Q_A(t)$ or $m_A(t)$, and second signal portion sequence $B(t)$ is mixed with a portion of second signal portion sequence $B(t)$ (of reflection signal $r(t)$) reflected by the at least one object 20 to form a second mixed signal $I_B(t)$, $Q_B(t)$ or $m_B(t)$. For this purpose, frequency analyzer 43 forms a complex spectrum $M_A(k)$ of complex mixed signal $m_A(t)$ over frequency x and a complex spectrum $M_B(k)$ of complex mixed signal $m_B(t)$ over frequency k . Using detector 44, frequencies k_A of complex mixed signal $m_A(t)$ (that is, with respect to first signal sequence $A(t)$) and the frequencies k_B of complex mixed signal $m_B(t)$ (that is, with respect to second signal sequence $B(t)$) are ascertained.

Radar device 30 has an evaluator 45 for determining the distance R and/or the differential speed v . For this purpose, evaluator 45 solves the following system of equations:

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

where c is the speed of light.

5 In addition there may be a provision for detector 44 also to ascertain the difference $\Delta\psi$ between the phase of complex mixed signal $m_A(t)$ and the phase of complex mixed signal $m_B(t)$. For example -- for determining distance R and/or speed difference v -- evaluator 45 may be used to solve the following
10 overdetermined system of equations, e.g., by a least square algorithm:

$$\Delta\psi = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + \frac{2R \cdot f_{Shift}}{c} \right)$$

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

There may be an additional provision to use more than two
15 signal portion sequences. Thus, for example, three signal portion sequences $A(t)$, $B(t)$ and $C(t)$ of different differential frequency $f_{Hub,A}/(N-1)$, $f_{Hub,B}/(N-1)$ and $f_{Hub,C}/(N-1)$ may be used and suitably emitted and processed. For example -- for determining distance R and/or speed difference
20 v -- evaluator 45 may be used to solve, for example, the following overdetermined system of equations, for example, by a least square algorithm:

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

$$\kappa_C = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,C}$$

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$$\Delta\psi_{AB} = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + 2R \cdot \frac{f_{T,B} - f_{T,A}}{c} \right) \text{ where } f_{T,B} - f_{T,A} = f_{Shift,BA}$$

$$\Delta\psi_{AC} = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + 2R \cdot \frac{f_{T,C} - f_{T,A}}{c} \right) \text{ where } f_{T,C} - f_{T,A} = f_{Shift,CA}$$

10 Accordingly there may be a provision to use, appropriately
emit and process, for example, four signal portion sequences
A(t), B(t), C(t) and D(t) of different differential frequency
 $f_{Hub,A}/(N-1)$, $f_{Hub,B}/(N-1)$, $f_{Hub,C}/(N-1)$ and $f_{Hub,D}/(N-1)$. For
example -- for determining distance R and/or speed difference
15 v -- evaluator 45 may be used to solve, for example, the
following overdetermined system of equations, for example, by
a least square algorithm:

$$\kappa_A = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,A}$$

$$\kappa_B = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,B}$$

$$\kappa_C = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,C}$$

$$\kappa_D = \frac{2v \cdot f_T}{c} \cdot (N-1) \cdot T_{Burst} - \frac{2R}{c} \cdot f_{Hub,D}$$

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$\Delta\psi_{AB}$ = see above

$\Delta\psi_{AC}$ = see above

$$\Delta\psi_{AD} = -2\pi \cdot \left(\frac{2v \cdot f_T \cdot T_{Burst}}{c} + 2R \cdot \frac{f_{T,D} - f_{T,A}}{c} \right) \text{ where } f_{T,D} - f_{T,A} = f_{Shift,DA}$$

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In addition, a different time duration may be provided for the signal portions of different signal sequences.

Fig. 5 illustrates an exemplary embodiment for an optical
10 measuring device 50 for the improved measurement of speed
difference v or distance R . Optical measuring device 50 has
an optical sensor 60 and an evaluation device 61, which
corresponds essentially to evaluation device 41. Optical
measuring device 50 has an oscillator or a signal generator 51
15 for producing a transmission signal $sl(t)$, a laser 55 for
emitting light at the frequency of transmission signal $sl(t)$
and a photoelement 56 for receiving a light reflected by at
least one object such as obstacle 20 and for producing a
reflection signal $rl(t)$ at a frequency corresponding to the
20 frequency of the reflected light. The transmission signal
 $sl(t)$ produced by signal generator 51 corresponds to
transmission signal $s(t)$, but is located in another frequency
range. Via a coupler 52, transmission signal $sl(t)$ is
supplied to a mixer 58 for mixing transmission signal $sl(t)$
25 and reflection signal $rl(t)$. Mixer 58 outputs an inphase
signal $I(t)$.

Via another coupler 53, transmission signal $sl(t)$ is
additionally supplied to a phase shifter 57, which shifts the
30 phase of transmission signal $sl(t)$ with respect to the carrier
frequency by 90° , that is, by $\pi/2$. The phase-shifted
transmission signal is supplied to a mixer 59 for mixing the
phase-shifted transmission signal and the reflection signal

$r_1(t)$, which is supplied to mixer 59 via a coupler 54. Mixer 59 outputs a quadrature signal $Q(t)$.

5 The elements, signals and frequency ranges in the Figures are drawn with simplicity and clarity in mind and not necessarily to exact scale. Thus, for example, the orders of magnitude of some elements, signals or frequency ranges are exaggerated in order to facilitate understanding .

LIST OF REFERENCE CHARACTERS

	1	motor vehicle
	2, 3	bumper
	4, 5	side mirror
5	6, 7	side door
	8	hatchback
	10, 14, 15, 16	distance and/or speed sensor
	20	object or obstacle
	30	radar device
10	51	signal generator
	33, 34, 52,	
	53, 54	coupler
	35	transmitting antenna
	36	receiving antenna
15	57	phase shifter
	39, 58, 89	mixer
	40	radar device
	41, 61	evaluation device
	42	multiplier
20	43	frequency analyzer
	44	detector
	45	evaluator
	50	optical measuring device
	55	laser
25	56	photoelement
	60	optical sensor
	A, B	signal sequence
	A1, A2, A3, B1,	
	B2, B3	signal portion
30	$f_{Hub,A}$, $f_{Hub,B}$	difference between the carrier frequency of the first signal portion of a signal portion sequence and the carrier frequency of the last signal portion of the signal portion sequence
35	f_{Shift}	frequency shift

	$f_T(t)$	carrier frequency
	$I(t)$	inphase signal
	$m(t)$	complex mixed signal
	$M(\kappa)$	complex spectrum
5	$Q(t)$	quadrature signal
	R	distance
	$r(t), r_l(t)$	reflection signal
	$s(t), s_l(t)$	transmission signal
	t	time
10	T_{Burst}	time duration
	v	speed difference
	v_F	speed of the motor vehicle
	v_H	speed of the obstacle
	$\Delta\psi$	difference in the phase of two mixed
15		signals
	κ	frequency
	κ_A, κ_B	measured frequency of a complex mixed
		signal